DOCUMENT RESUME

ED 275 720 TM 860 634

AUTHOR Posner, Michael I.; Rothbart, Mary Klevjord
TITLE The Concept of Energy in Psychological Theory. Cognitive Science Program, Technical Report No. 86-2.
INSTITUTION Oregon Univ., Eugene. Dept. of Psychology.
SPONS AGENCY Office of Naval Research, Arlington, Va. Personnel and Training Research Programs Office.
REPORT NO ONR-86-2
PUB DATE 1 May 86
CONTRACT N00014-83-K-0601
NOTE 49p.; Paper presented at the NATO Advanced Research Workshop on Energetical Aspects of Human Information Processing (Les Arcs, France, August 23-28, 1985).
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Arousal Patterns; *Attention; *Cognitive Processes; *Cognitive Psychology; Individual Differences; Inhibition; *Neurological Organization; Neurology; Personality Development; Stimuli
IDENTIFIERS Brain Functions; Energetics

ABSTRACT

This paper describes a basic framework for integration of computational and energetic concepts in psychological theory. The framework is adapted from a general effort to understand the neural systems underlying cognition. The element of the cognitive system that provides the best basis for attempting to relate energetic and computational ideas is selective attention. Based on empirical studies in the areas of temperament, development, cognition and neuropsychology, this paper outlines what is currently known about the organization of several neural systems in selective attention. It confronts the issue of how selection is influenced by energetic processes, such as arousal, emotion, and individuality. Attention is viewed as a part of the complex biological system that modulates the basic reactivity of the organism through self regulation. (JAZ)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

Cognitive Science Program

THE CONCEPT OF ENERGY IN PSYCHOLOGICAL THEORY

BY

MICHAEL I. POSNER

AND

MARY BOUWHUIS ROTHBART

Technical Report No. 86-2

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

University of Oregon

Research Sponsored by:

Personnel and Training Research Programs
Psychological Services Division
Office of Naval Research
Under Contract No. N000.14-83-K-0601
ONR No. 86-2

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1 REPORT NUMBER ONR No. 86-2	2. GOVT ACCESSION NO.	3 RECIPIENT'S CATALOG NUMBER
4 TITLE (and Subtitle) The Concept of Energy in Psychological Theory		5 TYPE OF REPORT & PERIOD COVERED Final Report 6 PERFORMING ORG. REPORT NUMBER
7 AUTHOR(s) Michael I. Posner and Mary Klevjord Rothbart		8 CONTRACT OR GRANT NUMBER(s) N00014-83-K-0601
9 PERFORMING ORGANIZATION NAME AND ADDRESS		10 PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 667-523
11 CONTROLLING OFFICE NAME AND ADDRESS		12 REPORT DATE May 1, 1986 13 NUMBER OF PAGES 47
14 MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15 SECURITY CLASS. (of this report) Unclassified 15a DECLASSIFICATION/DOWNGRADING SCHEDULE

16 DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17 DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18 SUPPLEMENTARY NOTES

19 KEY WORDS (Continue on reverse side if necessary and identify by block number)

cognition, emotion, temperament, energetics, arousal, attention, neuropsychology, development

20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

We seek to understand the integration of computational (information processing) concepts of cognition and energetics (arousal, emotion, temperament). We briefly outline the traditions out of which concepts of cognition and energetics arise. We argue that the integration of these concepts is best done at the level of the component facilitations and inhibitions describing elementary cognitive operations modulated by midbrain arousal systems. We explore this integration for the area of selective attention by defining a hierarchical selective attention system in terms of its mental operations and the neural systems supporting them.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE S/N 0102 LF 014 6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

This is a draft of a paper prepared for the NATO Advanced Research Workshop on: Energetical aspects of human information processing, Les Arcs, France 23-28 August, 1985

The Concept of Energy in Psychological Theory[1]

Michael I. Posner[2] and Mary Klevjord Rothbart

University of Oregon, U.S.A.

ABSTRACT

We seek to understand the integration of computational (information processing) concepts of cognition and energetics (arousal, emotion, temperament). We briefly outline the traditions out of which concepts of cognition and energetics arise. We argue that the integration of these concepts is best done at the level of the component facilitations and inhibitions describing elementary cognitive operations modulated by midbrain arousal systems[3]. We explore this integration for the area of selective attention by defining a hierarchical selective attention system in terms of its mental operations and the neural systems supporting them. We examine arousal (from warning signals, time of day, drugs and emotion) in terms of the activation of neurotransmitters and review how they might influence attention. We discuss how definitions of reactivity and self-regulation based upon these concepts are involved in temperament and personality. Although the paper is quite speculative, it makes close contact with current empirical studies in the areas of temperament, development, cognition and neuropsychology. These studies require further efforts to achieve integration of energetic and information processing ideas.

The Concept of Energy in Psychological Theory

Michael I. Posner and Mary Klevjord Rothbart

University of Oregon, Eugene, Oregon U.S.A.

Introduction

The first use of the term "energetics" in systematic psychological theory we were able to locate was in G.L. Freeman's book The Energetics of Human Behavior published in 1948. In this book he acknowledges his debt to Titchener, who first suggested to Freeman that physiological study might aid in understanding the relation of motivation to behavior. In this chapter we first trace the intellectual background to the energetic concept as employed by Freeman, Malmo, Duffy and others. Next we seek to establish links between this work and the information processing tradition. We believe that one key to making this connection lies in understanding the development of attentional systems early in life. Like Titchener (1908), we see attention as central to the psychological enterprise because it connects subjective experience and voluntary control to

human performance. Moreover, the concept of attention has roots in both physiology and information processing.

However, as currently used in information processing psychology, the direction of attention is almost invariably under the control of the experimenter, with issues of self regulation left aside. In our view the study of arousal, emotion and other energetic concepts help us see how the direction of attention is controlled by the organism. A clearer delineation of the mechanisms of self regulation allows distinctions between pathways involved in reactivity to environmental demands and those representing the regulation of those pathways by attention.

History of the Energetics Concept

The concept of energy, developed from Newtonian mechanics and elaborated by Maxwell's analysis of electromagnetism, was a major influence on 19th century physics. Then, as now, influential concepts in physics were of interest to psychologists who sought to provide a physical basis for psychological phenomena. Thus, Freud (1917) viewed the basic substructures underlying human motivation as sources of energy that could be blocked from expression in consciousness and behavior. The damming of intense energy led to emotional and

motivational problems for which psychoanalysis attempted relief. Although Freud believed an understanding of these central processes in terms of physiology was possible and desirable, the reflex oriented physiology of that century was not adequate to the task.

In 1947, two neurophysiologists working in Italy laid the groundwork for the development of central self-organizing mechanisms that were to revolutionize 20th century conceptions of brain processes. Moruzzi and Magoun (1949) showed that lesions of the midbrain reticular activating system produced comatose animals who could not be aroused. By 1949, Hebb relied upon the new understanding of the complex physiology of central states to direct the attention of the psychological community to the dual function of stimuli. Each stimulus cues the organism and provides an increment of arousal that maintains the alert state. In this view there could be no complete processing of a stimulus without concomitant effects upon the arousal system. By 1962, Duffy had synthesized this view with a description of a general arousal dimension separable from the direction of behavior and measurable in central, autonomic and skeletal responses that allowed the organism to maintain low thresholds and rapid responses to events.

The unified arousal concept could never account for the highly differentiated pattern of activation accompanying the primary emotions, and in 1967 Lacey pointed to dissociations among autonomic,

cortical and somatic arousal systems. These psychological analyses were further supported by new findings from immunofluorescent techniques showing highly differentiated patterns of neurotransmitter pathways involved in maintaining cortical electrical activity (Cooper, Bloom and Roth, 1978). There was no longer any need to postulate a single arousal system. Rather the separate neurotransmitter systems had the capability of producing a number of forms of arousal that could be related to emotional and motivational psychological functions.

In the meantime, 19th century reflex physiology had also undergone great change, due mainly to efforts by Pavlov to describe the changes in cortical functioning that accompany the formation of new associations. Reflex thinking was no longer confined to the study of simple innate connections between stimulus and response, but could be extended to describe changes in habit strength for non reinforced stimulation and new associations resulting from reinforced presentations. These modifications were based upon underlying processes of facilitation and inhibition that allowed the same stimulus to control behavior or to be ignored depending upon momentary changes in its ability to excite internal systems.

Pavlov also observed important variability across individuals in laboratory functioning that led him to posit individual differences in strength of excitation, strength of inhibition, balance between excitatory and inhibitory strength and mobility. These dimensions

have formed the basis for a scientific study of temperament in numerous Soviet and East European laboratories (Strelau, 1983). Strelau has developed a theoretical position identifying individual differences in sensitivity and endurance as indicators of nervous system strength, and the amount and range of activities undertaken or avoided as indicators of self-regulation. In addition, he assesses individual differences in "temporal traits", including speed and tempo of reactions, and mobility of nervous processes, ie, efficiency of reacting to rapidly changing stimulus conditions. These energetic constructs allow for study of individual differences within a general theoretical framework related to strength of the nervous system. The marriage of subcortical arousal systems to flexible associations due to habituation and conditioning provides a system for the interaction of learning, arousal, temperament and emotion that appears more adequate for developing a theory of energetics.

Theories of motivational systems (Derryberry and Rothbart, 1984; Panskepp, 1981) stress the development of higher level controls over preexisting reactive processes. A regulative emotion like fear may thus be potentiated by hormonal conditioned stimuli. Once released, organized defensive or escape behaviors and patterns of information intake are set in motion, influencing lower levels of response and sensory intake.

Information Processing and Cognitive Psychology

The 20th century has been called the era of information just as the 19th was called the era of energy. The science of information which spawned the computer has had an enormous impact upon psychology. The idea of the brain as a form of computer has also served us well in producing an objective science of cognition. At one level it is possible to specify the computations necessary to perform a cognitive act in terms of subroutines or elementary operations. This approach has been applied to problem solving (Newell & Simon, 1972), to visual processing (Marr, 1982) and to the comprehension and production of language (Chomsky, 1965). In each of these areas, specification of the logical computations needed to produce cognition has aided in fostering an experimental science that studies whether and how such computations are performed by humans.

For example, working memory is an important human constraint on solving problems and comprehending. Thus, it has been of interest to specify the nature of this constraint by studies of its capacity limits (Baddeley, 1981). Since object recognition appears to require transformation of input in order to relate it to stored representations, there have been dozens of experimental studies of mental rotation (Shepard, 1978) and other transformations. These studies provide information on the ability of people to execute the elementary operations thought to be the logical basis of cognition. In this way the study of cognition has transformed the computer metaphor into an experimental analysis of basic human capacities.

Of course it has always been clear that problems of motivation and emotion are not very well captured in this approach to psychology (but for a different view see Simon, 1979). Some information processing psychologists pursued just such topics, often because their interest in practical applications or individual differences required such a concern. However, for the most part those interested in information processing could avoid this issue by identifying their interest as cognition (e.g. the logic of computation) and excluding these issues as unrelated.

Certain topics did prove to be embarrassing even to this approach. One of these was attention. In lay language attention has to do, at least in part, with our subjective experience of things. This concept is of no importance to a computer system. When it appeared that some important processing went on prior to or outside of attention, Broadbent remarked in puzzlement,

> "it seems to require a biologically unlikely kind of machinery...it seems to mean that the part of the brain which analyzes inputs from the environment, and which presumably is quite complicated, is preceded by another and duplicate part of the brain which carries out the same function, deciding what is there in order to reject or accept items for admission to the machinery which decides what is there." (Broadbent, 1978 page 67).

One solution to this issue was to view attention as a limited resource that could be allocated to different cognitive systems (computational modules) (Navon & Gopher, 1979). Thus, attention appeared as an energy which mysteriously served to improve the efficiency of information processing. This mixture of energetic and computational ideas provided one way of accommodating energetic ideas to an information processing theory, but it did not serve to tell us very much about how they relate to each other. There have been additional efforts to accomodate emotion to information processing theory (Bower 1981; Mandler, 1984) but most of them do no more than to identify emotion as another node within a semantic memory network. The energetic concept of emotion relating activity to the dissipation of accumulated energy, has simply not been readily manageable within the information theoretic framework.

Neural Systems of Cognition

The possibility of integrating energetic and computational ideas in psychology is emerging from efforts to relate and perhaps even understand computation in terms of underlying neural systems. In our view this is not a matter of reducing cognition to neurophysiology but rather of obtaining ways of using information from both fields to provide additional constraints on theory (Posner, in press).

19th Century neurology provided some very valuable analytic tools for dealing with aspects of cognition. The 19th century has been called the period of the great diagram makers. These neurologists emphasized disconnections between areas as the basic explanation for the types of aphasia seen in the clinic (Geschwind, 1965). The problem with this approach was the lack of specification of what computations were performed within each of the relevant neural areas. This left accounts of cognition consisting largely of arrows connecting centers whose functions were vague. Moreover, the lack of theories of normal language production left such diagrams subject to the argument that the pathology itself was producing new phenomena rather than revealing the presence of connection found in normal brains. The development of modern cognitive theories of reading (Marshall & Newcombe, 1973; Coltheart, 1985) has begun to specify the types of computation to be performed within each module as well as the connections between modules that could support normal and pathological performance. This emphasis upon computation has grown within current cognitive psychology in all subareas.

How can we understand the way nervous systems compute? The language of the nervous system is often specified in terms of facilitation and inhibition of individual neural units while the language of computation is usually specified in terms of functional operations whose input and output is specified. A major development in recent cognitive psychology is the specification of computations in

terms of component facilitations and inhibitions in performance (Feldman & Ballard 1981; Rumelhart & McClelland, 1982). Recent connectionist models have been proposed that emphasize the similarity of the component operations to the synaptic computations of neurons (Feldman & Ballard, 1981). This has led to greatly increased contact between neuroscience and computational models of human performance.

There is evidence relating facilitation and inhibition in performance to the action of neural cells. A number of years ago one of us began to explore the connections between the enhancement of individual neural cells during acts of visual attention in animals and the facilitations found in human performance bring similar paradigms. The success of this enterprise has been discussed in a number of recent papers (Posner, Cohen & Rafal, 1982; Posner, Walker, Friedrich & Rafal, 1984; Posner, Choate, Rafal & Vaughan, 1985; and Posner, in press). These papers argue from studies with patients that the parietal lobe is responsible for decoupling attention from a current focus, while midbrain systems are involved in the act of moving attention from that focus to its new location. This spatial attention system is linked in a hierarchical fashion to systems involved in more general attentional acts such as selecting concepts from memory, generating motor activity, etc. (Posner, Inhoff, Friedrich & Cohen, in process).

Although it is not possible to review these results in detail, they lead us to the tentative conclusion that there are strong and

detailed connections between facilitations and inhibitions found in chronometric experiments on attention and the enhancement of single neural cells. The areas of damage in patients which produce these deficits are those predicted from single cell recording (Wurtz, Goldberg & Robinson, 1980). If this work is correct, one approach to an integration of energetic and information processing concepts is within the field of attention. Selective attention mechanisms can be specified to some degree in terms of cognitive and neural systems. If we can say how arousal modulates the component facilitations and inhibitions in selective attention, we will have taken a step toward understanding how selection comes to be controlled by the organism's own energetic systems (arousal, emotion). This provides an approach to understanding how self-regulation is mediated.

Arousal and Selectivity

Much of modern neurophysiology is based upon work with anaesthetized animals whose sensory systems react to stimuli imposed by the experimenter. Of course even such anesthetized preparations regulate input by responses, as for example in changes in pupil size to light. In psychology these passive mechanisms are called "automatic" because they involve pathways either built in (as in pupil size adjustments) or learned (as in activation of the phonological

code of a visual word for a skilled reader). Psychologists are also interested, however, in a higher level regulation or control which the organism exercises over input. This active level of regulation involves selective attention and is sometimes called controlled processing. Systems of arousal as induced by emotion, stress or stimulation may affect either or both of these forms of information processing.

How does arousal affect information processing computations? The physiology of arousal systems is quite complex. Separate neurotransmitter systems include acetycholine, norepinepherine, dopamine, GABA, opiates and others. It is difficult to determine how these systems relate to one another in general, but combining analyses of information processing and physiology may allow us to make some useful speculations.

Turning first to the performance data, there appear to be two major ways in which changes of efficiency of responding to visual signals might occur. First, information about sensory pathways automatically activated by input are activated more efficiently. Priming of a word by a physically or semantically related word acts in this way to improve pathway activation. This effect involves reactivity and is outside of attention, but would clearly improve the speed and accuracy of overall performance (Posner, 1978). Second, the efficiency of orienting attention might be improved so that a given visual signal reaches the attention system more rapidly. Warning

signals appear to influence the rapidity with which signals reach attention rather than the speed of pathway activation (Posner, 1978).

Reactivity

The presentation of a stimulus produces many parallel effects of neural functioning. For visual stimuli there is input directly both to cortical levels and to the subcortical centers responsible for alerting effects. Changes in reactivity may also be modulated by environmental factors (e.g. diurnal cycles) and differ between individuals. Indeed, Eysenck (1967) has defined one basic dimension of personality in terms of the organism's reactivity to sensory stimulation, with extraverts being low on this dimension and introverts high on it.

Time of day appears to be related to the sensory thresholds and processing speeds for a large variety of signals. This effect can be dissociated from the general increase in metabolic activity reflected in body temperature. One cycle which appears to be related to performance is the variation in blood levels of cortisol and other glutocorticoids. It is also known that reduced levels of these substances in Addison's disease can lead to abnormally low sensory thresholds (Henkin, 1970). Moreover, these substances can easily pass the blood-brain barrier and are related to stimulation of norepinepherine by neural cells (Wesnes & Warburton, 1983).

Norepinepherine in turn is known to have the effect of increasing the signal to noise ratio by amplifying the effect of synaptic transmission in neural cells. Thus, the effects of time of day and of norepinephrine secretion might best be seen as related to very general increases in synaptic activity such as would improve neural transmission throughout the system. As a result, a visual signal would be processed more rapidly throughout its pathway.

In addition to the general reactivity of cortical systems psychologists have found it possible to modify individual pathways for brief periods through priming. The presentation of a stimulus appears to activate internal systems (logogens) which are then more easily reactivated for a brief period. In this way, the potential reactivity of the organism to any given event may be continually modified by context. While repetition has usually been found to improve the efficiency with which a pathway can be activated, it is also often accompanied by a reduction in evoked potential amplitude. One view of this phenomenon is to suppose that repetition of a given stimulus habituates its ability to produce cortical arousal while leaving intact or even amplifying the strength of specific pathway activation (Kraut, 1976; Posner, 1978). According to this view, reactivity as defined here may be counteracted by attentional systems (self-regulation).

Self Regulation

By self regulation we mean here the control over reactivity that can be exercised through selective attention. Attention as we understand it is an integrated cognitive system with its own anatomical base (Posner, 1982). Although the neural systems subserving selective attention are not fully known, it is possible to describe some parts of them, particularly those closely related to visual-spatial attention (Posner, Walker, Friedrich & Rafal, 1984; Posner, Choate, Rafal & Vaughan, 1985; Posner, in press; Wurtz, Goldberg & Robinson, 1980).

Attention may serve a number of functions. Some functions proposed for attention are as follows: to conjoin features within and across modalities (Treisman & Gelade, 1980), to govern access to awareness and to non habitual responding (Posner, 1978) to foster semantic processing and integration of input into unified propositions, etc. In order to understand the mechanisms of selective attention, it is useful to have model systems to study attentional influence over simple types of sensory and motor responding. As we see it a single attention system allocates to different sensory and motor analyzers the appropriate mechanisms allowing the performance of various complex mental operations. We call this view a hierarchical distributed network. One of the major functions of this network is to give priority to operations based upon the current goals of the person. Thus, sensory input may only have access to output when its processing is in accord with the current motives of the organism.

The idea that higher brain systems exercise inhibitory control over lower ones is an old one in physiology (Sechenov, 1965). Recent research suggests that the system responsible for selective attention may influence even very elementary levels of information processing. For example, there is some evidence that the attention system affects simple unisynaptic reflex activity (Olbrich-Rodriguez, 1985). When subjects' attention was focussed on the leg receiving a tendon tap the amplitude of T reflex was suppressed. During divided attention tasks, the amplitude of the T reflex varied directly with the difficulty of the processing task as measured by increased response time to perform voluntary responses to a probe task. This result suggests that attention serves to inhibit the strength of reflex activity and also to speed responses to voluntary events. Thus, attention may serve to allow non habitual responses to occur more efficiently.

There has been a great deal of effort directed toward an understanding of selective attention to visual input. One impetus for this research has come from single cell recording in alert monkeys (Mountcastle, 1978; Wurtz, Goldberg & Robinson, 1980). When the monkey attends to a peripheral stimulus there is selective enhancement of firing rates of neurons in various areas of the brain. When the attention involves an eye movement there is enhancement in the midbrain (superior colliculus) and in the frontal lobe (frontal eye fields). When the attention shift is covert a similar enhancement is found only in the area of the posterior parietal lobe.

It seemed important to determine if these facilitations in cellular activity were related to the priorities in reaction time and thresholds occurring when attention is cued to a visual location (Posner, 1980; Posner, Cohen & Rafal, 1982). To examine this relationship we used patients with midbrain and parietal lesions (Posner, Walker, Friedrich, & Rafal, 1984; Posner, Choate, Rafal & Vaughan, 1985). Our findings showed that the parietal lesion produced a deficit in the ability of patients to shift attention covertly from a current focus to engage a target in the contralateral direction. Lesions of the superior colliculus and surrounding midbrain areas which prevented saccades also tended to slow covert shifts of attention as though the ability to move attention in the affected direction was impaired. This work showed that the cortical and subcortical areas cooperate to control shifts of visual-spatial attention.

In the following paragraphs we review some detailed models of how subcortical systems affect cortical processes. Recently Petersen, Morris & Robinson (1984) have injected small amounts of GABA agonists and antagonists into the pulvinar. The pulvinar is an important thalamic visual relay system between midbrain and cortical areas that have been related specifically to visual spatial attention (Wurtz, Goldberg & Robinson, 1980). They found enhancement of covert shifts of visual attention in the direction contralateral to the injection of the GABA agonist and the reverse effects for the antagonist. There

are known close links between GABA and serotonin. The serotonin agonist, methysergide, has also been found to be helpful in the treatment of a disorder (progressive supranuclear palsy) which reduces the ability to shift visual-spatial attention. These findings suggest a possible role for GABA and serotonin in the control of visual-spatial orienting of attention.

If a warning signal is presented prior to delivering a target event or if the reticular formation is stimulated prior to a visual task there is improved performance in the speed of processing which may be accompanied by a decrement in accuracy (Posner, 1978). At the cortical level these effects are reflected in a desynchronization of the EEG in both hemispheres. Such electrocortical arousal is thought to be mediated by ascending cholinergic pathways (Warburton, 1975) with strong connections to frontal and hippocampal sites.

In 1978, one of us introduced a theory which was designed to describe the relationship of the arousal (alerting) induced by a warning and subsequent performance (Posner, 1978). According to this view, the cue acted to change the rate at which the central attention system could respond to the buildup of information about the identity of the target, although it did not affect the rate of that buildup (Posner, 1978). We now know that a cue also has a powerful directional affect of drawing attention toward its internal location (e.g., the sensory system in which it occurs and its location within a cortical map) (Posner, 1980).

Can we separate the energetic effect of arousal (alerting) from the directional effect? A neat dissociation of the two has recently been reported in studies of damage to the parietal lobe (Posner, Inhoff, Friedrich & Cohen, in process). We found that right and left parietal patients show about equal deficits in the ability to disengage attention from a current visual focus toward a contralateral target; however, right patients have a much larger deficit than lefts in the general alerting effect of the cue. If the cue is omitted, right patients in comparison with normals or lefts show a massive increase in reaction time. This result confirms evidence favoring an asymmetry in normals and patients. The asymmetry in normals identifies the right hemisphere with greater sensory activation (Heilman & Watson, 1977; Tucker & Williamson, 1984). Our results show that the deficits in activation produced by right hemisphere lesions can be dissociated from the directional effects of the cue on spatial orienting.

In this section we have attempted to relate "arousal" induced by cues to selective mechanisms. In brief, we have identified different neurotransmitters arising in midbrain systems with the functions of general activation of pathways, covert orienting of visual-spatial attention and a general activation of an attentional command system. In one sense this can be seen as a more detailed working out of the proposal made by Broadbent (1971) to divide arousal effects into upper and lower mechanisms, of the suggestions of McGuiness and Pribram

(1980) and of our own previous efforts to distinguish between pathway activation and attentional effects (Rothbart & Posner, 1985).

Emotion

Naloxone is an opiate antagonist. The administration of opiates to monkeys tends to block erection and sexual desire, while naloxone has the effect of increasing erections and other evidence of sexuality. Thus, naloxone is a chemical which plays a role within a natural form of arousal involving the body's opiate system. We can ask what effect such a form of arousal has upon selective attention. Recently, human subjects were injected with low levels of naloxone or a placebo control prior to undergoing a selective listening task (Arnsten, Neville, Hillyard, Janowsky & Segal, 1984.). The naloxone produced enhanced selectivity as measured by N1 at frontal sites and some improvement in signal detection, but no change in arousal as measured by mood ratings or autonomic measures. There is good reason to believe that N100 is a specific brain sign related to selectivity of information (Hillyard, Hink, Schwent & Picton, 1973) and it may be part of a general tendency of attention to a pathway to mark that pathway by a negativity (Harter & Aine, 1984; Naatanen, 1982).

This example provides evidence favoring a role for opiates in reducing the efficiency of processing input information. Since the release of such opiates (eg, from taking drugs or naturally following

intercourse) produces a stuporous state, a reduction in the efficiency of attention to external stimuli should come as no surprise. Although in this study (Arnsten et. al., 1984) naloxone administration did not produce an emotional or mood change, it is likely that opiate release is generally accompanied by emotional euphoria and sense of well being.

Are emotional changes generally accompanied by shifts in information processing efficiency? There is evidence from psychological studies of some of these effects. Thus, Broadbent (1973) found that processing of emotional words appeared to change the sensitivity of the visual system in favor of lower spatial frequency information. It is as though the arousal which might accompany emotional responses changes the bias of attention to more global channels. Bower (1981) has shown that induced moods also lead to a general bias in favor of memories whose emotional tone mirrors the current mood state.

According to our general framework, it is important to examine the time dynamics of mental processes in terms of their component facilitations and inhibitions. Is it possible to think of the activity of emotional reactions in this way? Recently, Derryberry (1984) has developed a very interesting online assay of emotion that seems to have the potential of providing a good analysis of emotional lability both in normals and other subjects. He defined a reaction time criterion. The subject must be faster than this criterion in

order to be rewarded for success on that trial. This is followed by a cue indicating either that the subject is capable of winning points (if fast and correct) or a cue indicating that points can be only lost (if slower than the criterion or incorrect). A neutral cue means that on this trial the subject can neither win nor lose points. This is followed by a single target word which can be either positive, neutral, or negative in tone. The subject's task is to classify that word. Following the classification the subject gets feedback as to whether points were won or lost.

Derryberry's reasoning is that the incentive signal sets off a positive or negative expectancy. If the signal indicates the subject can win points, it sets a positive expectancy. If points can only be lost and not won, it sets a negative expectancy. These emotional sets influence the subject's processing of positive or negative words. Following each trial the outcome information together with the subject's incentive produces six possible conditions. Positive incentive and positive outcome is called joy, negative incentive and positive outcome relief, neutral incentive and positive outcome success. Negative incentive and negative outcome is called loss, positive incentive and negative outcome frustration, and neutral incentive and negative outcome, failure.

Do moods induced by the cues influence performance? If one looks within a trial, the incentive cue interacts with the word in such a way that positive incentives make the processing of positive words

more efficient and negative incentives make the processing of negative words more efficient. It is likely that this effect operates via attention since there are both costs and benefits when compared with the neutral incentive condition.

There are other interpretations of this within trial effect. It could be that subjects bias their responses for cognitive rather than emotional reasons. However, the effect of the previous outcome on performance on the next trial is less likely to be influenced by cognitive factors. The outcome of the previous trial has no objective consequences for performance on the next trial, which are equally likely to have positive and negative incentives or words irrespective of the overall performance. However, a very interesting effect is found on subsequent trials. Positive outcomes on the previous trials make efficient the processing of negative words while negative outcomes make efficient the processing of positive words. This combination of an effect within trials that is congruent with the cue, and an effectacross trials that is incongruent with the mood, is reminiscent of the attentional effects found in spatial attention. With spatial orienting it is found that when a subject is cued to attend to a given location there is increased efficiency in processing items at that location, but on the next trial, the previously advantaged location is now disadvantaged (Posner & Cohen, 1984). Whether Derryberry's effects are in fact similar to those found with spatial attention is a question requiring further research.

Derryberry's method has a nice characteristic of time-locking possible emotional changes to cues.

In this section we have tried to examine energetic effecs on selectivity from a viewpoint consistent with our general framework by considering information processing and physiological data in terms of component facilitations and inhibitions. Both arousal following informative cues and changes in performance consequent to emotion have been examined.

Individuality

Individuals differ in their reactivity to stimuli and in the degree to which they can control such reactions (Rothbart & Derryberry, 1981). Numerous views of temperament postulate individual differences in reactivity. Pavlov's (1935) work on "strength" of nervous system, Strelau's (1983) on reactivity and Eysenck's (1967) on introversion-extroversion suggest that more reactive individuals will reach "optimal levels" of stimulation at lower stimulus intensities than less reactive individuals. In Eysenck's view more reactive introverts will tend to avoid intense levels of stimulation, while the less reactive extroverts will seek out and approach situations involving high levels of intensity, complexity and novelty.

Adult Studies

How do differences in reactivity relate to the levels of self-regulation through selective attention? To approach this issue a questionnaire was administered to a large sample of adult subjects (Derryberry & Rothbart, 1984). The questionnaire contained subscales assessing reactivity, emotionality and self-regulation. The reactivity construct was correlated across scales dealing with cortical, behavioral and autonomic reactivity (r=.3-.5). The negative affects (fear, frustration, sadness, and discomfort) were also substantially intercorrelated (r=.5).

There was generally a positive correlation between reactivity and negative affect, with more reactive individuals showing a greater tendency toward negative affect. The research also indicated a significant role for self regulation in mediating relationships between reactivity and affect. Measures of attentional focusing and attentional shifting were consistently and negatively related to negative affect. Thus, individuals who report they can effectively concentrate and shift their focus of attention may be able to attenuate the relations between reactivity and negative affect. There is good experimental evidence (Keele & Hawkins, 1983) that the ability to orient attention is a capacity which is correlated across a variety of conditions. The current results suggest that ability to control attention may be instrumental in preventing the individual from being

overwhelmed by negative feelings (see also Lewinsohn, Hoberman, Teri & Hautzinger, 1985 for a similar view with respect to clinical depression).

Development

We believe that study of the development of temperament is essential to a full understanding of how attention and other controls come to regulate affective states. During the period of infancy, individual temperament is revealed in a relatively pure form, before it can be influenced by extensive experience or the development of conceptual systems. In this initial state of the infant, these individual characteristics are chiefly reactive, with development modifying temperament through the maturation of self regulatory systems in interaction with experience.

The earliest model for the study of individual differences in reactivity and its modification by attention can be found in the study of control of the eye movement system. Posner and Cohen (1980) have identified a sign of retinal-collicular control that is quite prominent in eye movements in the infant. This sign is the tendency to turn toward the temporal direction when equivalent stimuli are presented simultaneously on the nasal and temporal side of fixation. A study by Mendelson and Haith (1976) of newborns showed clear evidence of a temporal bias by each eye, and Lewis, Maurer, & Kelly

(1985) have also reported that with a single stimulus presented monocularly, newborns show a powerful bias in the direction of the temporal visual field. This strong bias drops out over the first two months of life.

Thus, newborns appear to show particularly strong signs of the retinal-to-collicular pathway, even with unilateral stimuli. The influence of the nasal visual field appears to be weak, and this changes dramatically over the first two months of life. In adults, the influence of the retinal-collicular pathway can be demonstrated, but the temporal advantage is demonstrated only when there is genuine competition between the stimuli. These data are in agreement with the general outline of Bronson's (1974) view of a shift from midbrain to cortical control over the early months of life. They do not, however, require a dichotomy between midbrain and cortical control, but instead argue for a steady increase in more central control over the eye movement system.

Cholinergically controlled control mechanisms appear to mature at about 2-3 months of age in the human. Graham, Strock and Ziegler (1981) have provided a recent review of the maturation of cardiac control, noting that noradrenergic excitatory effects (heart rate acceleration) are dominant immediately postnatally in human infants, with cholinergic heart rate deceleration observed most clearly only after 2-3 months of age. Graham et al. note that in developing rats, early motor excitatory effects become increasingly regulated through

cholinergic mechanisms by about 15-20 days of age. They suggest that the onset of strong heart rate decelerations in the orienting of human infants may also be evidence of increasing cholinergic control. In addition to heart rate deceleration, orienting reactions include motor quieting and negative shifts in EEG, indexing increased receptivity to stimuli. These effects resemble alerting in response to a warning signal by older children and adults (Posner, 1978), and may be labelled a "response preparation" period.

An additional temperament dimension clearly identifiable by 7-9 months of age is behavioral inhibition, i.e., the inhibition of approach responses. Schaffer (1974) has observed that although infants of 5 months demonstrate via their looking patterns that they can distinguish between novel and familiar objects, they reach equally quickly to both novel and unfamiliar objects. At 8 months, however, they show greater hesitancy in grasping the novel toy. A discrepancy or novelty checking apparatus is clearly in place before 7 months since it influences differential visual orienting to novel versus familiar stimuli. Now, however, novelty also demonstrates influences the development of approach responses via behavioral inhibition.

At the reflexive level, inhibition involves built-in reflexes, e.g., inhibition associated with orienting, or inhibition built up in the repetition of non-reinforced stimuli or during passive avoidance conditioning. This is called internal inhibition, and it is seen to function in spontaneous alternation. According to Luria (1961), the

capacity for internal inhibition should provide an underlying mechanism for the development of both conditioned and verbal self control. We (Reed, Pien and Rothbart, 1984) have found a positive relation between a measure of internal inhibition (spontaneous alternation) and two measures of verbally regulated behavioral inhibition (a pinball game and simon-says) in children aged 40-49 months. All of these measures showed strong age effects.

Krakov and Johnson (1981), using different measures of self control with younger children (age 18-30 months), also found a behavioral inhibitory cluster and large age effects with moderate levels of stability of inhibitory self-control across a 12-month period. Taken together, these studies indicate that there are increases in verbal self-regulation across 1-1/2 to 4 years of age. Our study suggests there may also be increases in internal inhibition relatively late in development.

There are good reasons to suppose that the development of frontal systems is closely related to this level of behavioral inhibition. It has been known for some years that monkeys with frontal lesions have great trouble in the delayed response task. Recently it has been found (Diamond & Goldman-Rakic, 1984) that such monkeys have great difficulty in any situation in which a dominant response tendency must be held in check in order for a correct response to be made. For example, frontal monkeys cannot seem to inhibit visually controlled reaching in order to guide the hand to an open aperture to extract a reward (Diamond, 1981).

The delayed response task appears to be one in which the previously rewarded response gains dominance over the visually observed location with delay on a given trial. Thus animals who are unable to avoid the dominant response make erroneous responses with increased delays. Infants before a year of age appear to exhibit the same inability to inhibit dominant response tendencies as do monkeys. Our understanding of the basic neurobiology of frontal systems is undergoing rapid development (Goldman-Rakic, 1984) and there is a good prospect that the neural systems which underly this form of self-regulation will soon be better understood. It is clear that frontal systems responsible for this kind of inhibitory control are part of the circuits that have strong relationships to the visual-spatial attention system of the parietal lobe. Thus, we can identify these systems with the attentional command mechanisms that seem to play an important role in controlling covert spatial orienting. These systems appear to continue to develop for some years and may thus relate to other forms of self-regulation that we have described as occuring later in childhood.

Theoretical Summary

In this paper we have attempted to provide a basic framework for integration of computational and energetic concepts. The framework is adapted from a general effort to understand the neural systems

underlying cognition (Posner, 1984). The element of the cognitive system that provides the best basis for attempting to relate energetic and computational ideas is selective attention. Accordingly, we have outlined what is currently known about the organization of several neural systems in selective attention. In doing so, we have sought to confront the issue of how selection is influenced by such energetic processes as arousal, emotion and individuality. In other words we have tried to view attention as a part of the complex biological system that modulates the basic reactivity of the organism through self regulation. An example would be damping down patterns of overreaction to environmental events that might lead to negative affect. Attentional skill may allow the person to give priority to other events, thus reducing negative feelings.

The general issue raised by our paper is an old one: how do emotional reactions to events relate to our cognition? The direction we favor is neither the simple idea that cognitions create our emotions by providing appropriate differentiated labels to a general arousal response (Schacter & Singer, 1962; Mandler, 1975) nor the artificial separation of the two systems (Zajonc, 1980), nor an emphasis on peripheral facial mechanisms, but rather a program of sustained research to trace energetic and computational events in terms of their component facilitations and inhibitions in information processing and then to observe the origins of these components in the neural systems that support them. We think the papers in this conference will aid in following that lengthy and complex direction.

References

1. Arnsten, A.F.T., Neville, H.J., Hillyard, S.A., Janowsky, D.S. and Segal, D.S. (1984). Naloxone increases electrophysiological measures of selective information processing in humans. Journal of Neuroscience, 2912-2919.

2. Baddeley, A. (1981). The concept of working memory. Cognition, 10, 17-23.

3. Bower, G.H. (1981). Mood and memory. American Psychologist, 36, 129-148.

4. Broadbent, D.E. (1971). Decision and stress. New York: Academic.

5. Broadbent, D.E. (1978). In defense of empirical psychology. New York: Academic Press.

6. Bronson, G. (1974). The postnatal growth of visual capacity. Child Development, 45, 873-890.

7. Chomsky, N. (1965). Aspects of the theory of syntax. Cambridge, Mass: MIT Press.

8. Coltheart, M. (1985). Cognitive neuropsychology of reading. In Posner, M.I. & Marin, O.S.M. (Eds.). Attention and performance XI. Hillsdale, N.J.: Erlbaum.

9. Cooper, J.R., Bloom, F.E. & Roth, R.H. (1978). The hierarchical basis of neuropharmacology. New York: Oxford Press.

10. Derryberry, D. (1984). The role of emotion in information processing: incentive value and outcome influences on word categorization and target detection talks. Unpublished paper, University of Oregon.

11. Derryberry, D. and Rothbart, M. Emotion, attention and temperament. In C.E. Izard, J. Kagan, and R. Zajonc (Eds.). Emotion, cognition and behavior. Cambridge, England: Cambridge University Press, 1984.

12. Diamond, A. (April, 1981). Retrieval of an object from an open box. The society for research in child development, Boston.

13. Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. Child Development, 56, 868-883.

14. Diamond, A. and Goldman-Rakic, P.S. (1983). Comparison of

performances in a Piagetian object permanence task in human infants and rhesus monkeys: Evidence for involvement of prefrontal cortex. Society for Neuroscience Abstracts, 9, 641.

15. Duffy, E. (1962). Activation and behavior. New York: Wiley.

16. Eysenck, H.J. The biological basis of personality. Springfield, Ill: Charles C. Thomas, 1967.

17. Feldman, J.A. & Ballard, D.H. (1981). Connectionist models and their properties. Cognitive Science, 6, 205-254.

18. Freeman, G.L. (1948). The energetics of human behavior. Ithaca: Cornell University Press.

19. Freud, S. (1979). Introductory lectures on psychoanalysis. In Strachey, J. (Trans. & Ed.).The complete psychological works, vol. 15. New York: Norton.

20. Geschwind, N. (1968). Disconnection syndromes in animals and man. Brain, 237-294, 585-644.

21. Goldman-Rakic, P.S. (1984). The frontal lobes: uncharted provinces of the brain. Trends in neuroscience, 425-429.

22. Graham, F.K., Strock, B.D., and Ziegler, B.L. Excitatory and inhibitory influences on reflex responsiveness. In W.A. Collins (Ed.). Aspects of the development of competence. Hillsdale, NJ: Erlbaum, 1981.

23. Harter, M.R. & Aine, C.J. (1984). Brain mechanisms of visual selective attention. In Parasuraman, R., Davies, R. & Beatty, J. (Eds.). Varieties of attention. New York: Academic, 1984.

24. Hebb, D.O. (1949). Organization of behavior. New York: Wiley.

25. Heilman, K.M. & Watson, R.T. (1977). The neglect syndrome. In Harnad, S. (Ed.). Lateralization in the nervous system. New York: Academic Press.

26. Henkin, R.I. (1970). The neuroendocrine control of perception. In Perception and its disorders. Assoc. for research in nervous and mental disorders. Vol. 48, 54-107.

27. Hillyard, S., Hink, R.F., Schwent, V.L. & Picton, T.W. (1973). Electyrophysiological signs of selective attention in the human brain. Science, 182, 177-180.

28. Keele, S.W., and Hawkins, H.H. (1982). Explorations of individual differences relevant to high level skill. Journal of Motor

Behavior, 14, 3-23.

29. Krakow, J.B., and Johnson, K.L. The emergence and consolidation of self-control processes from 18 to 30 months of age. Paper presented at the meeting of the Society for Research in Child Development, Boston, April 1981.

30. Kraut, A.G. Effects of familiarization on alertness and encoding in children. Developmental Psychology, 1976, 12, 491-496.

31. Lacey, J.I. (1967). Somatic response patterning and stress: some revisions of activation theory. In M.H. Appley and Trumbull (Eds.). Psychol,ogical stress: Issues in research. New York: Appleton-Century-Crafts.

32. Lewis, T.L., Maurer, D. & Kelly, B. The development of young infants ability to detect stimuli in the nasal visual field. Vision Research.

33. Lewinsohn, P.M., Roberman, H., Teri, L, & Hautzinger, M. (1985). An integrative theory of depression. In S. Reiss & R.R. Bootzin (Eds.). Theoretical issues in behavior therapy. New York: Academic Press.

34. Luria, A.R. (1961). The role of speech in the regulation of

normal and abnormal behavior. New York: Liveright.

35. Luria, A.R. (1966). Higher cortical functions in man. New York: Basic Books.

36. Mandler, G. (1984). Mind and body: psychology of emotion and stress. New York: W.W. Norton.

37. Marr, D. (1982). Vision. San Francisco: Freeman.

38. Marshall, J.C. & Newcombe, F. (1973). Patterns of paralexia: a psycholinguistic approach. Journal of psycholinguistic research, 2, 175-199.

39. McGuinness, D. & Pribram, K. (1980). The neuropsychology of attention: Emotional and motivational controls. In M.C. Wittrock (Ed.). The brain and psychology. Los Angeles: University of California Press.

40. Mendelson, M.J. and Haith, M.M. (1976) The relationship between audition and vision in the human newborn. Monographs of the Society for Research in Child Development, 41 (4, Serial No. 167).

41. Milner, B. (1982). Frontal lobe deficit in humans. Proc. Royal

Soc. of London B. 298, 190-210.

42. Moruzzi, G. & Magoun, H.W. (1949). Brainstem reticular formation and activation of the EEG. EEG clinical neurophysiology, 1, 455-473.

43. Mountcastle, V.B. (1978). Brain mechanisms for directed attention. Journal of the Royal Society of Medicine. 71, 14-27.

45. Naatanen, R. (1982). Processing negativity: an evoked-potential reflection of selective attention. Psychological Bulletin, 92, 605-640.

44. Navon D. & Gopher, D. (1979). On the economy of the human information processing system. Psychological Review 86, 214- 255.

46. Newell, A. & Simon, H.A. (1972). Human problem solving. Englewood Heights, N.J.: Prentice Hall.

47. Olbrich-Rodriguez, E.W. (1985). Selective attention affects automatic responses. Unpublished doctoral dissertation, Univ. of Oregon.

48. Panskepp, J. (1982). Toward a general psychological theory of emotion. Behavior and brain sciences, 5, 407-467.

49. Pavlov, I.P. The essential works of Pavlov. New York: Bantam Books, 1961.

50. Petersen, S.E., Morris, J.D. & Robinson, D.L. (1984). Modulation of attentional behavior by injection of GABA-related drugs in the pulvinar of macaque. Society for Neuroscience abstracts, 10.

51. Porges, S.W. Peripheral and neurochemical parallels of psychopathology: A psychophysiological model relating autonomic imbalance to hyperactivity, psychopathy, and autism. In H.W. Reese (Ed.). Advances in child development and behavior. New York: Academic Press, 1976.

52. Posner, M.I. (1978). Chronometric explorations of mind. Hillsdale, NJ: Erlbaum.

53. Posner, M.I. (1980). Orienting of attention. Quarterly journal of experimental psychology, 32, 3-25.

54. Posner, M.I. (1982). Cumulative development of attentional theory. American psychologist, 32, 53-64.

55. Posner, M.I. A framework for relating cognitive to neural systems. EEG and clinical Neurophysiology, in press.

56. Posner, M.I., Choate, L., Rafal, R.D. & Vaughan, J. (1985) Inhibition of return: neural mechanisms and function. Cognitive neuropsychology, 2 (3), 211-228.

57. Posner, M.I. & Cohen, Y. (1980). Attention and the control of movements. In Stelmach, G.E. & Requin, J. (Eds.). Tutorials in motor behavior. Amsterdam: North Holland, 243-258.

58. Posner, M.I. & Cohen, Y. Components of visual orienting. (1984). In H. Bouma & D. Bouwhuis (Eds.). Attention and performance X. Hillsdale, N.J.: Erlbaum.

59. Posner, M.I., Cohen, Y. & Rafal, R.D. (1982). Neural systems of spatial orienting. Proceedings of the Royal Society London B 298, 187-198.

60. Posner, M.I., Walker, J.A., Friedrich, F. & Rafal, R.D. (1984). Effects of parietal lobe injury on covert orienting of visual attention. Journal of neuroscience, 4, 1863-1874.

61. Posner, M.I., Inhoff, A. & Friedrich, F. & Cohen, A. (1985). Isolating attention systems: a cognitive-anatomical analysis.

Unpublished manuscript.

62. Posner, M.I., Klein, R.M., Buggie, S. & Summers, J.J. (1973). On the selection of signals. Memory & cognition, 1, 2-12.

63. Posner, M.I., Nissen, M.J., Ogden, W.G. (1977). Attended and unattended processing modes: The role of set for spatial location. In H.J. Pick (Ed.). Modes of perception. Hillsdale, N.J.: Erlbaum.

64. Reed, M.A., Pien, D.P., and Rothbart, M.K. Inhibitory self-control in preschool children. Merrill-Palmer Quarterly, 30, 1984, 131-147.

65. Rothbart, M.K., and Derryberry, D. Development of individual differences in temperament. In M.E. Lamb and A.L. Brown (Eds.). Advances in developmental psychology (Vol. 1). Hillsdale, NJ: Erlbaum, 1981.

66. Rothbart, M.K and Posner, M.I. (1985). Temperament and the development of self-regulation. In Hartlage, L.C. and Telzrow, C.F (Eds.). The neuropsychology of individual differences: a development perspective, 93-123. New York: Plenum.

67. Rumelhart, D. & McClelland, J.L. (1982). An interactive activation model of context effects in letter perception. Psychological review, 89, 60-94.

68. Salapatek, P. (1968). Visual scanning of geometric figures by the human newborn. Journal of comparative and physiological psychology, 76, 247-258.

70. Schachter, S. and Singer, J.E. (1962). Cognitive, social, and physiological determinants of emotional state. Psychological Review, 69, 379-399.

71. Schaffer, H.R. Cognitive components of the infant's response to strangeness. In M. Lewis and L.A. Rosenblum (Eds.), The origins of fear. New York: Wiley, 1974.

72. Sechenov, I.M. (1965). Reflexes of the brain. Cambridge, Mass: MIT Press, 1965.

73. Shallice, T. (1982). Specific impairments of planning. Proc. of Royal Soc. of London B, 298, 199-207.

74. Shepard, R.N. (1978). The mental image. American psychologist, 33, 125-137.

75. Simon, H.A. (1979). Information processing models of cognition. Annual review of psychology, 30, 363-396.

76. Strelau, J. (1983). Temperament personality activity. New York: Academic Press, 1983.

77. Titchener, E.B. (1908). Lectures on the elementary psychology of feeling and attention. New York: Macmillan.

78. Treisman, A. & Gelade, P.A. (1980). A feature integration theory of attention. Cognitive psychology, 12, 97-136.

79. Tucker, P.M. & Williamson, P.A. (1984). Asymmetric neural control in human self-regulation. Psychologial review, 91, 185-215.

80. Wesnes, K. and Warburton, D. (1983). Stress and drugs. In R. Hockey (Ed.), Stress and fatigue in human performance. New York: Wiley.

81. Wurtz, R.H., Goldberg, M.E. & Robinson, D.L. (1980). Behavioral modulation of visual responses in monkey. Progress in psychobiology and physiological psychology, 9, 42-83.

82. Zajonc, R.B. (1980). Feeling and thinking: preferences need no inferences. American Psychologist, 35, 151-175.

Footnotes

1. This research is supported in part by the Office of Naval Research Personnel and Training Division under Contract No. N00014-84-K-0601 awarded to Michael I. Posner and by the National Institute of Public Health Grant No. 5T01 MH 26674 awarded to Mary K. Rothbart.

2. Currently at the Department of Neurology and McDonnel Center for Higher Brain Function, Washington University School of Medicine, St. Louis, MO 63110.

3. During the course of our conference there was much discussion of arousal as serving to change the gain on computations during task performance. This idea is certainly compatible to the idea of modulation of component facilitation and inhibitions developed in our chapter. We believe that the use of a framework allowing for combined information processing and neural systems analysis gives additional meaning to the concept of gain or modulation.